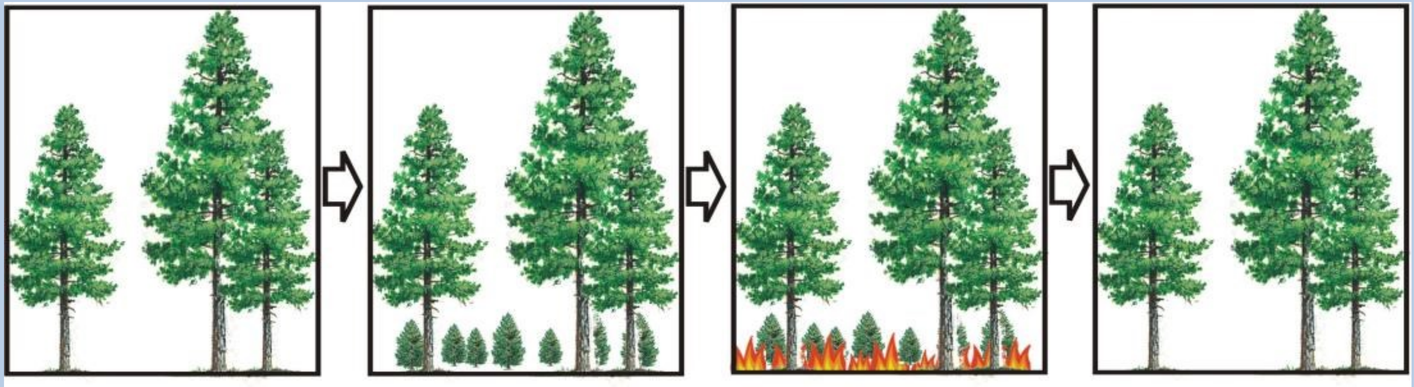
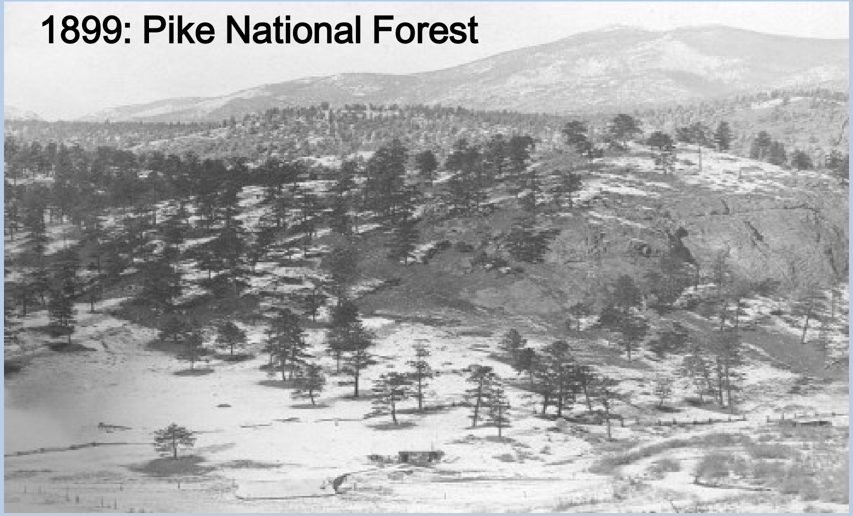
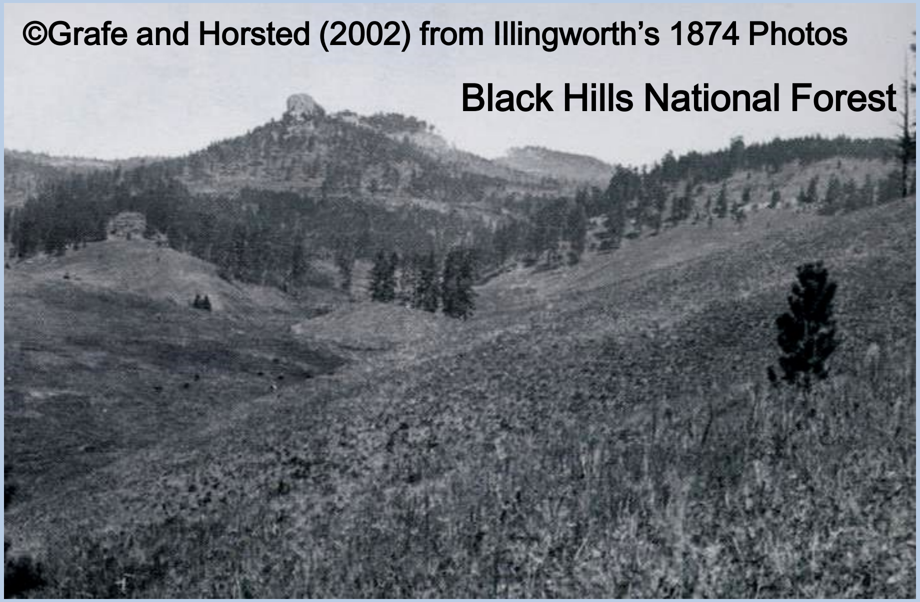
Restoration and fire behavior in ponderosa pine dominated forests

Justin Ziegler, Chad Hoffman, Mike Battaglia, W. ‘Ruddy’ Mell

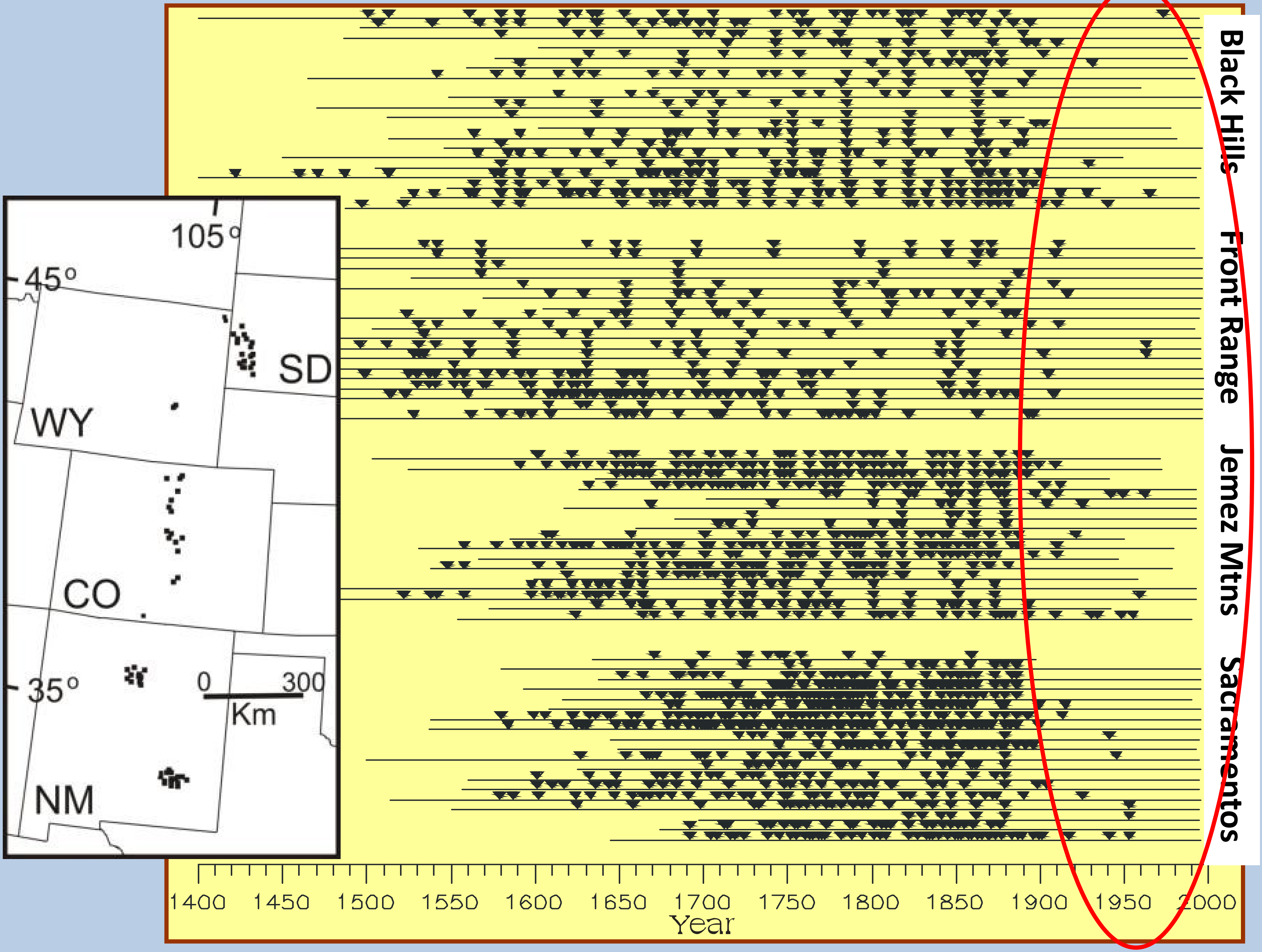
Historically, wildfires helped regulate forest structure and fuels in ponderosa pine dominated forests







Landscapes with complex structures of single trees, groups of trees, and various opening sizes.



105°
45°
35°
SD
WY
CO
NM
0
300
Km
Black Hills
Front Range
Jemez Mtns
Sacramentos
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
2000
Year

Shift to a landscapes of dense and contiguous forests


MAY 19 2006

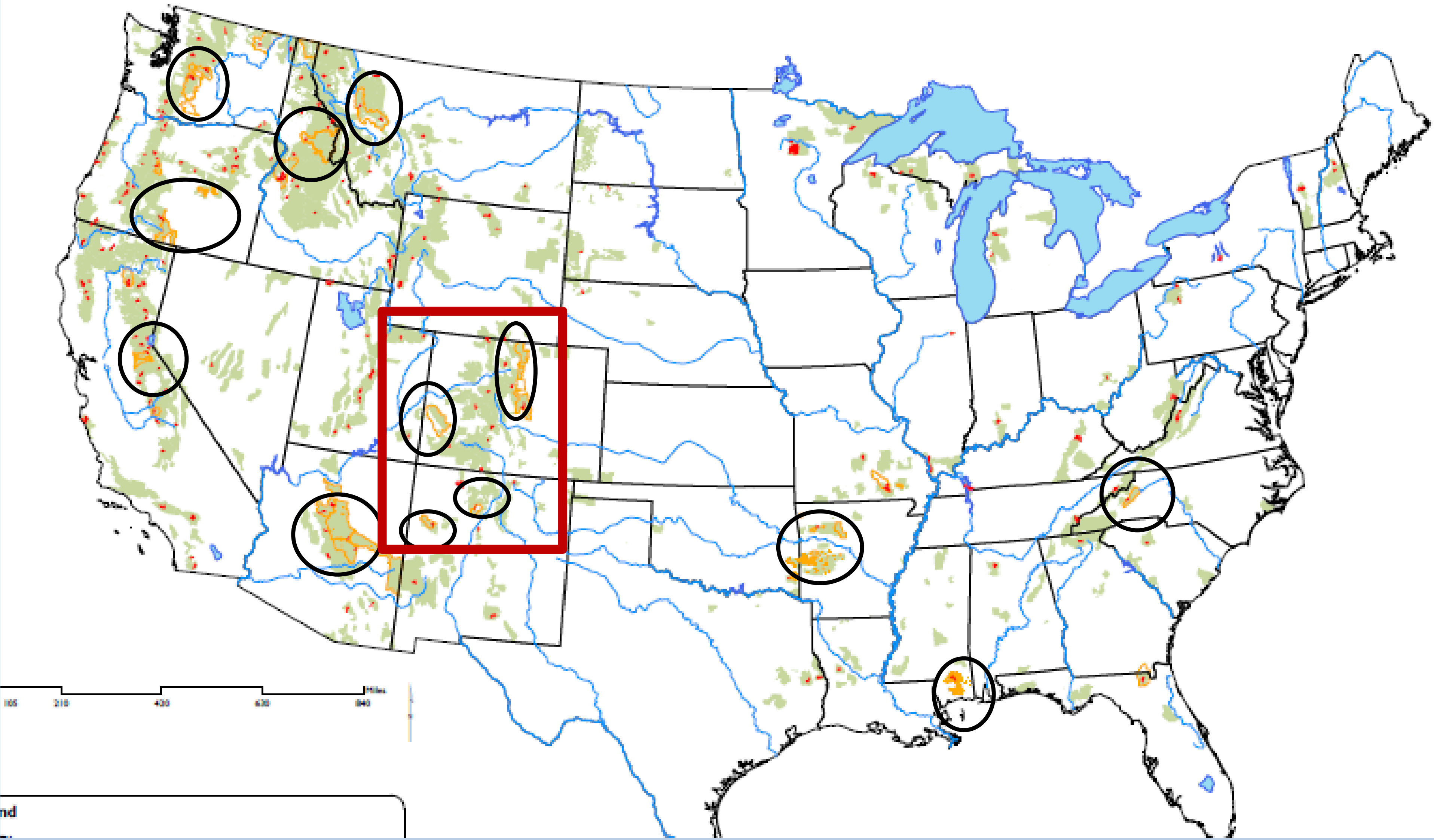

Photo courtesy of Blaine Cook




Helen Richardson, Denver Post

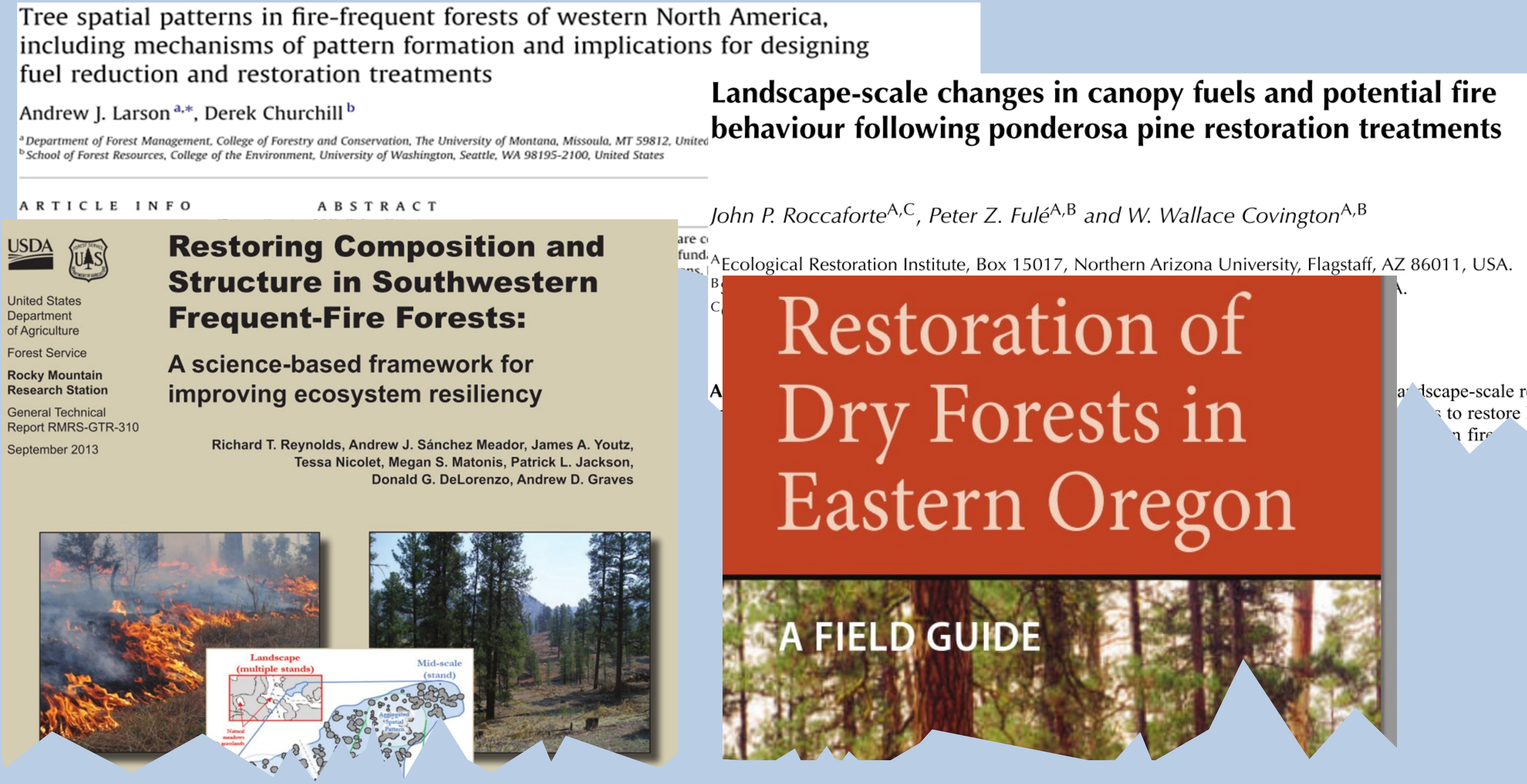

1899


Contemporary fuel hazard treatment
Photo: Gary Chancey, USFS



Collaborative Forest Landscape Restoration Program (CFRLP)

Restoration in ponderosa pine



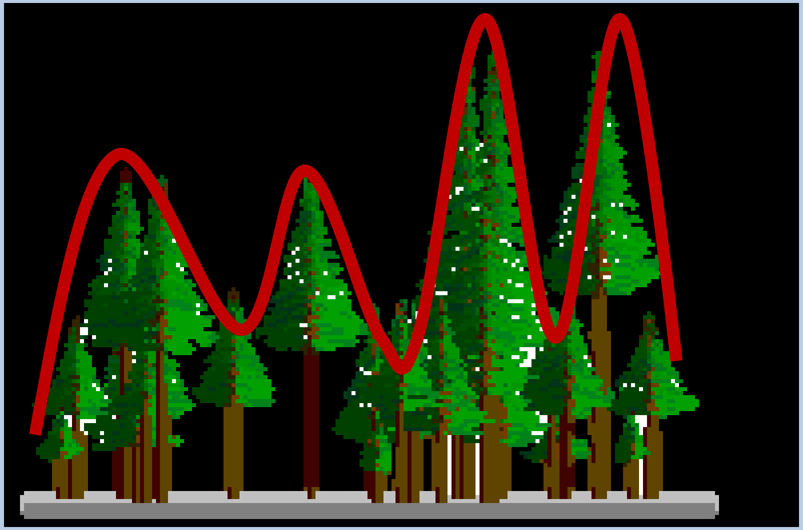
Two primary objectives:

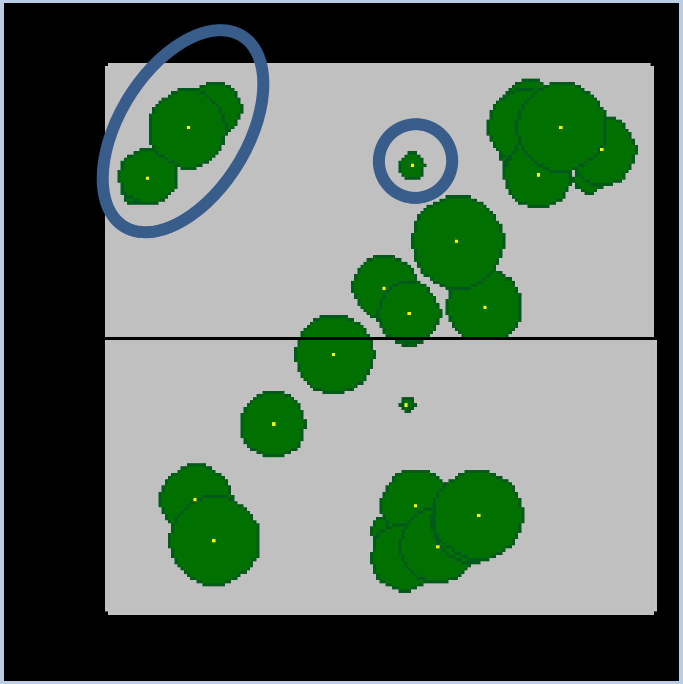
- Create stands with high structural complexity
- Reduce chances for hazardous fire behavior

What is structural complexity?

Complexity is *Scaled*:

- Stand-level—spatial properties characterizing the whole area of interest
- Patch-level—spatial properties within-stand features

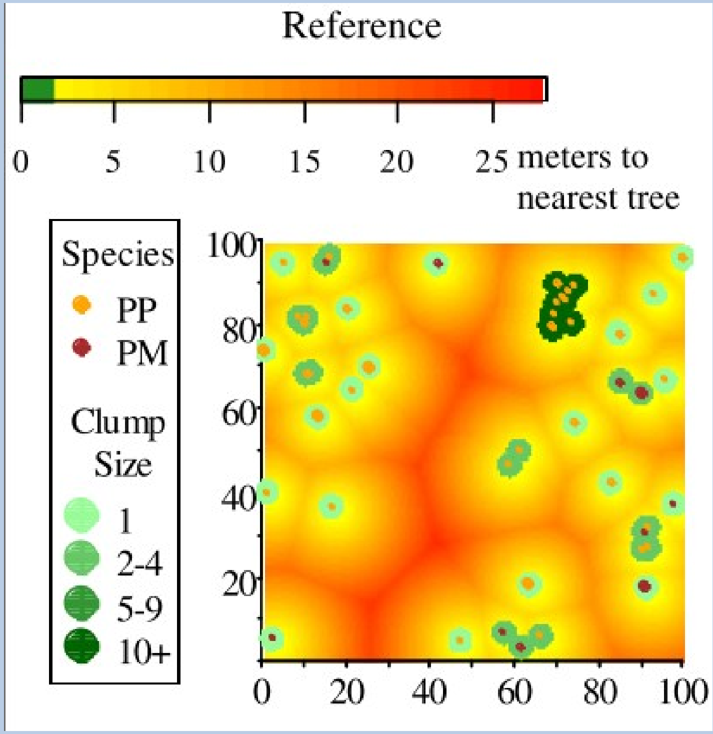




Implementing thinnings for structural complexity

Not so difficult when reference conditions available.

- Allows for adapting while implementing



Larson et al. (2013)

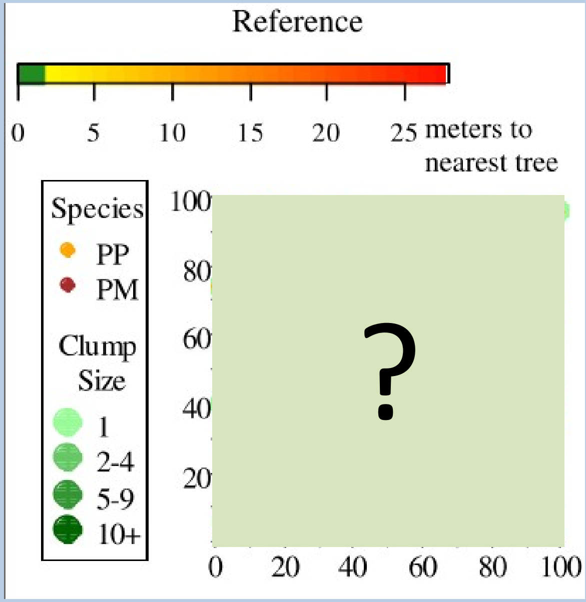
Implementing thinnings for structural complexity

But,

- Reference conditions are limited
- Biophysical settings vary

Silviculturalists are left with,

- Stand-averaged metrics



If aren't measuring complexity.. how do we know if we are we hitting the mark?

Larson and Churchill (2012)

Objectives

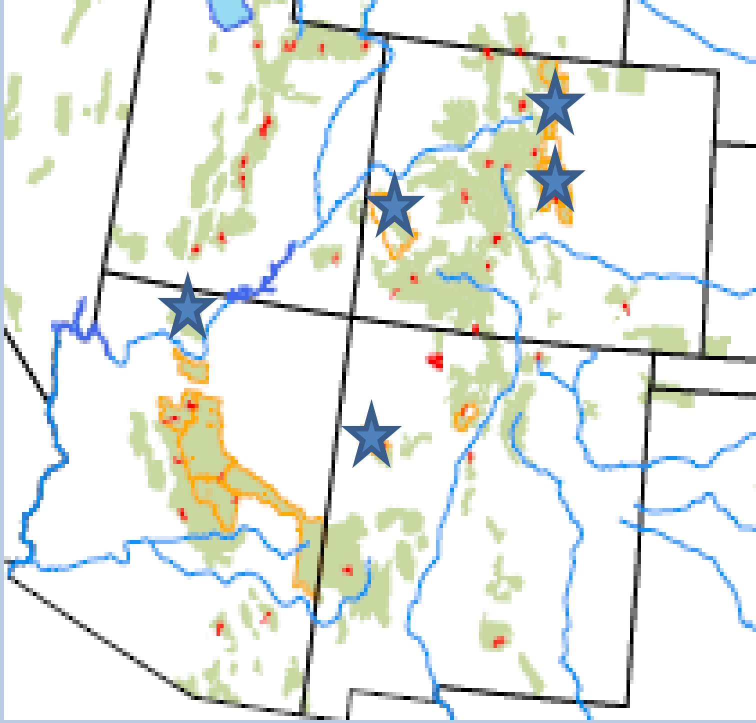
Assess the effect of forest restoration thinnings on structural complexity and fire behavior in frequent fire conifer forests.

Our specific aims were to:

1. Assess changes in structural complexity
    - Across horizontal and vertical dimensions
    - Across stand and patch scales

2. Evaluate impacts on potential fire behavior using the physics-based WFDS

Methods framework



Study site selection

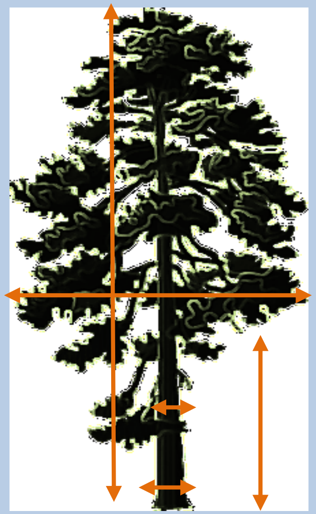
- 7 restoration thinnings across southern Rockies and eastern Colorado Plateau
- Ponderosa pine dominated
- Silvicultural ℞ emphasized:

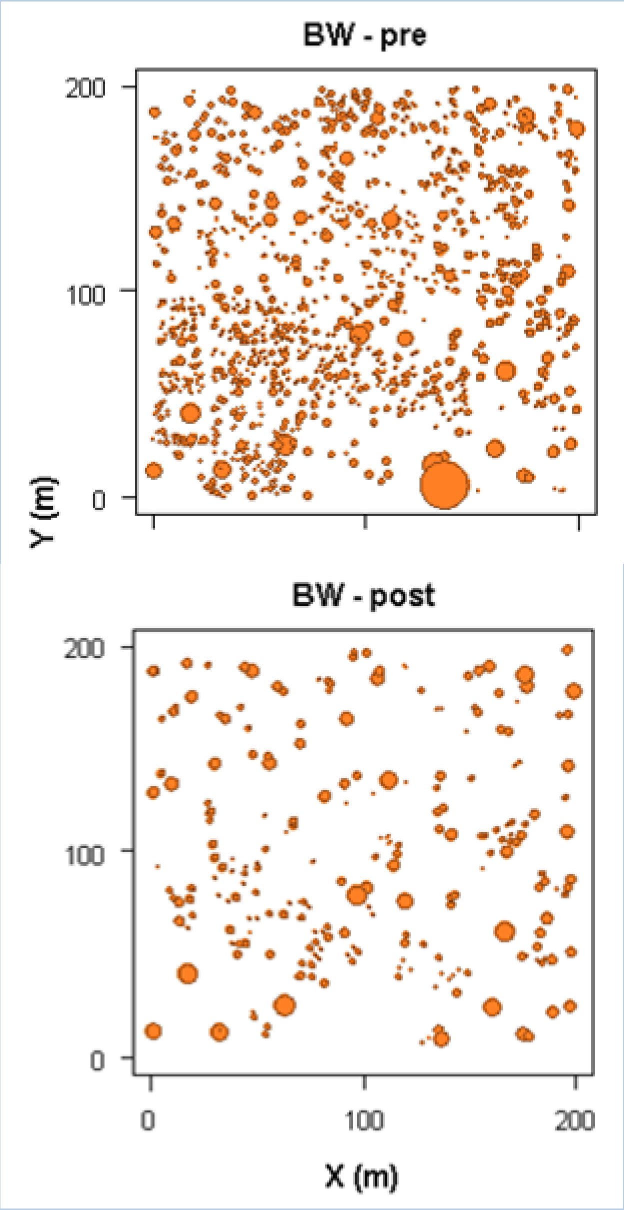
    - enhancing structural complexity (create openings, retain patches, increase aggregation, etc.)

    - fire hazard reduction

Structure/Fuels Inventory

- A single 200-m x 200-m plot per site
- All trees > 1.4 m height mapped
- Measured: height
  crown width
  crown base ht.
  DBH
  DSH





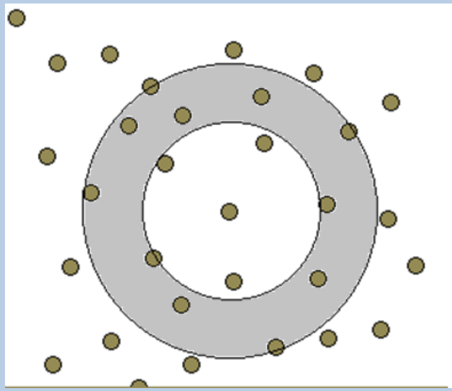
- All stumps mapped and DSH measured
- Regressions built to reconstruct stumps
- Surface fuels were systematically sampled across each unit and in an adjacent unthinned stand

Structural complexity analytical framework

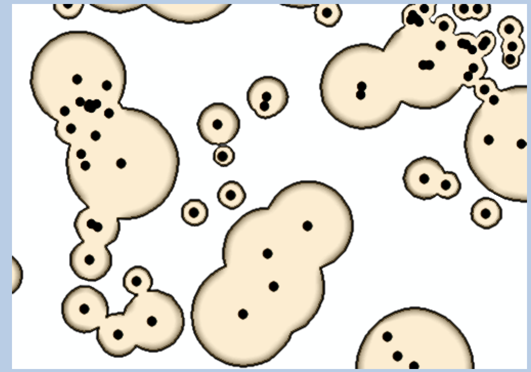
Dimension

Horizontal

Point correlation function

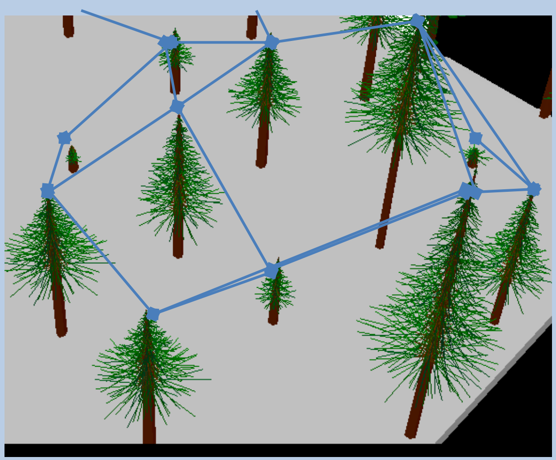


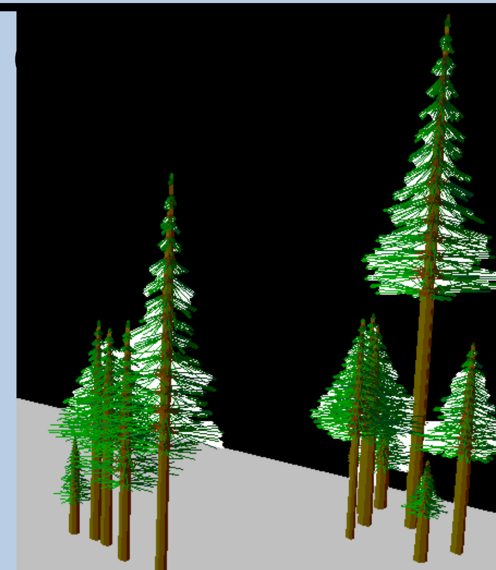
Patch detection



Vertical

Height Differentiation Index





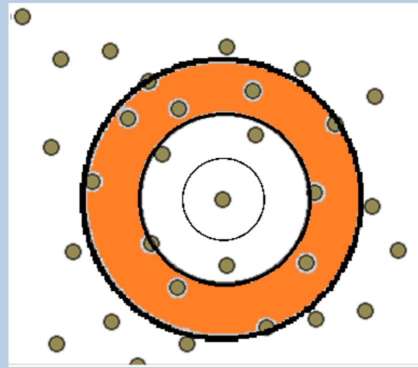
Stand

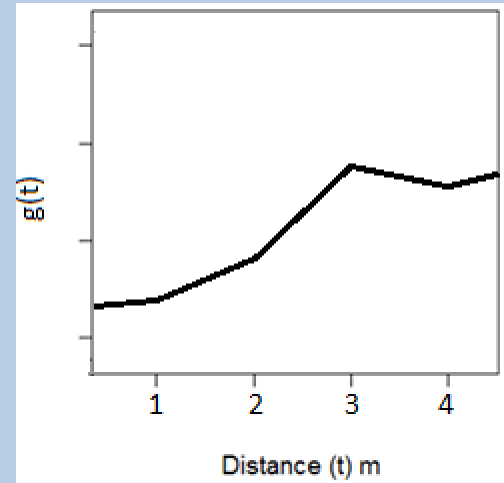
Patch

Scale

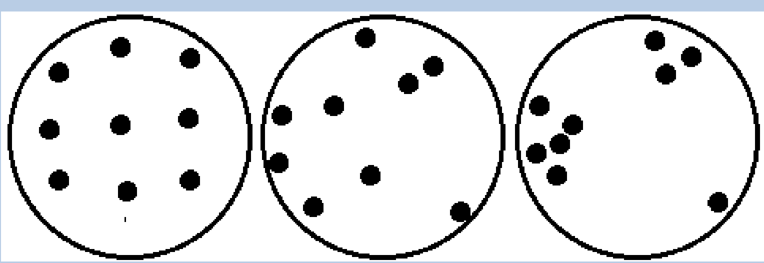
Point correlation function
(Horizontal Stand level)

- **Determines degree of aggregation at multiple scales**



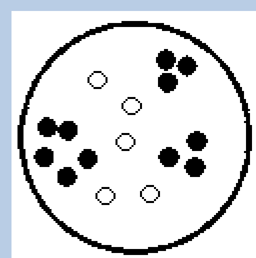


Question 1:
What spatial pattern resulted from thinning?

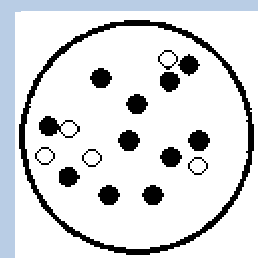


Uniform Random Aggregated

Question 2:
How do thinnings alter the degree of aggregation?



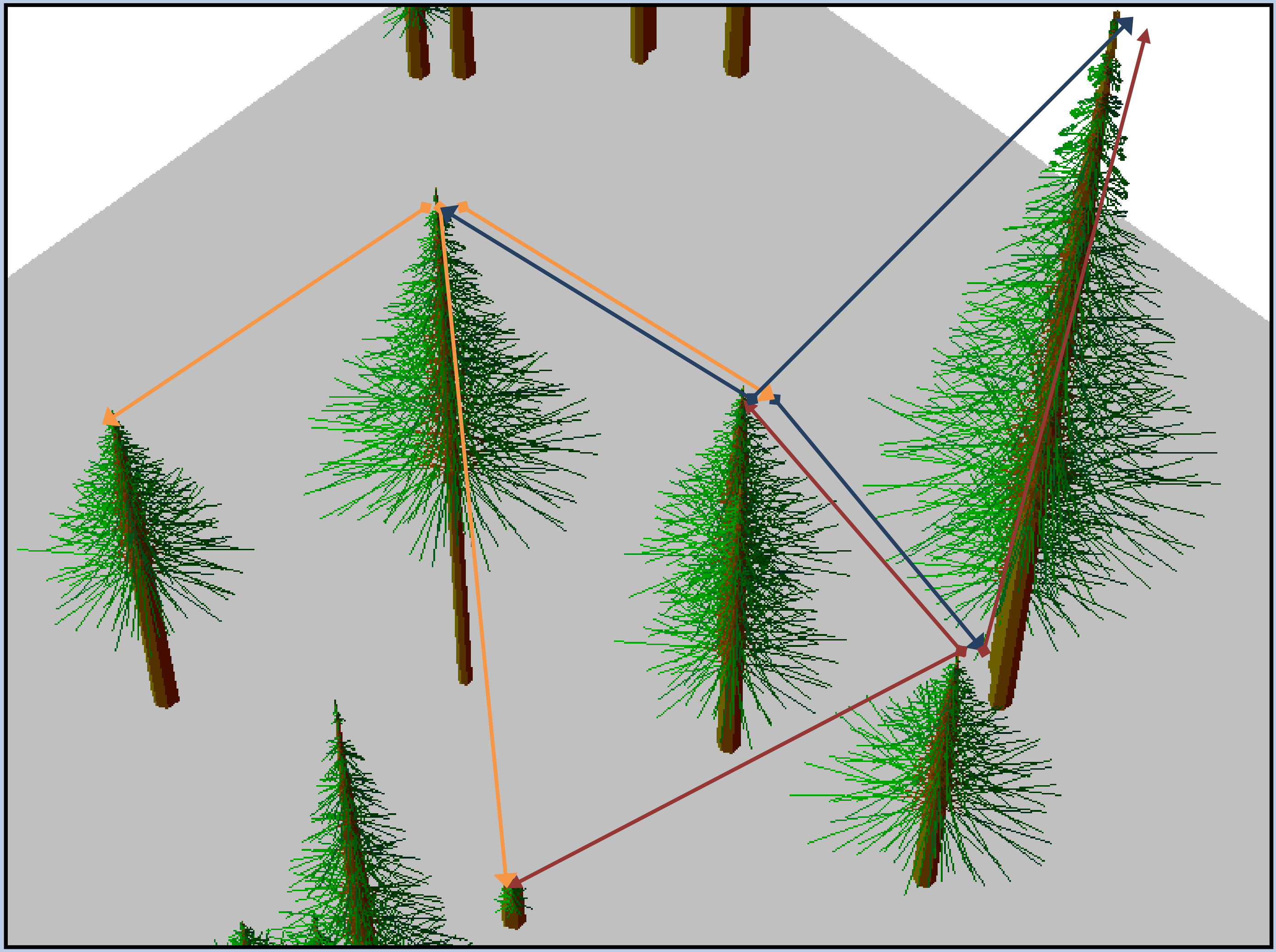
More



Less

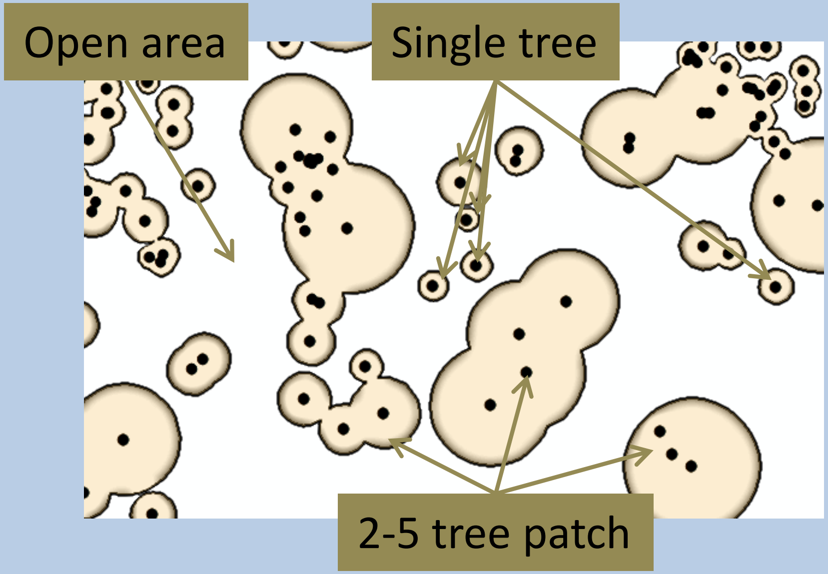
Height Differentiation Index
(*Vertical Stand level*)

Tree-centric index of height differences between neighboring trees



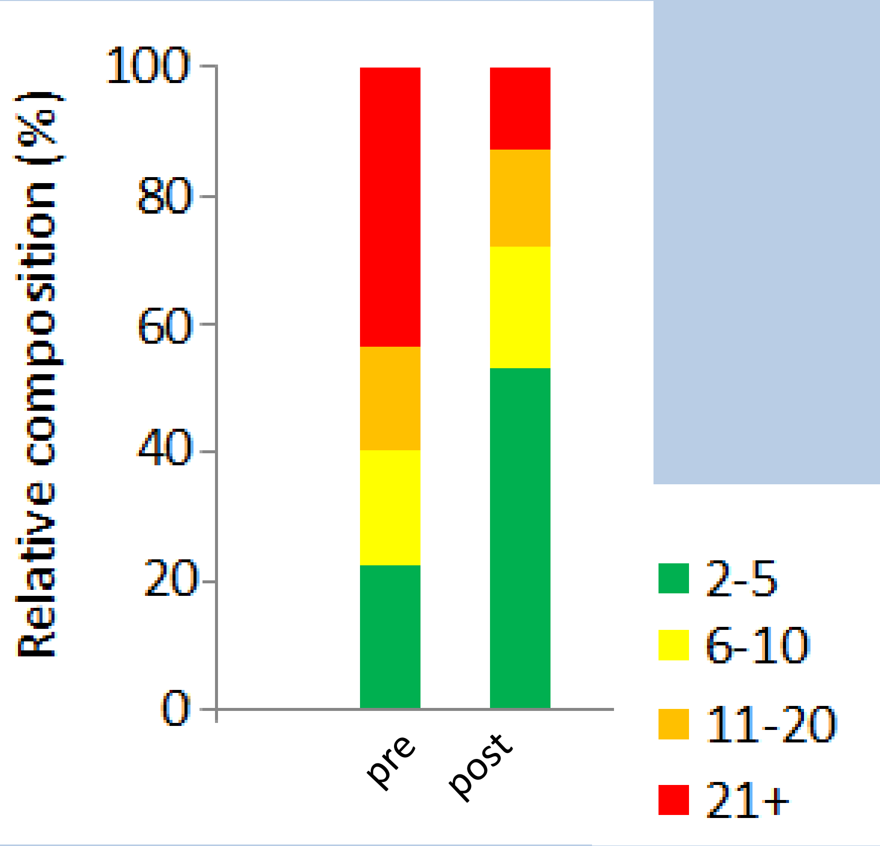
Complexity at the patch level

Patches—unique chains of trees with overlapping crowns.

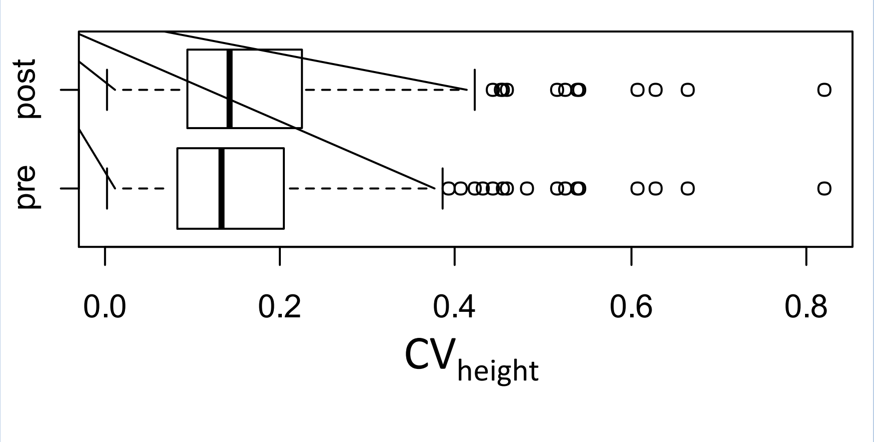


Patch detection

Explored changes in patch size distribution…



Vertical - coefficient of variation of patches' tree heights.



What does greater complexity look like?

Dimension / *Scale*	Stand	Patch
Horizontal	*Point correlation function* Aggregated pattern More aggregated following thinning	*Patch detection algorithm* Decrease in continuous cover (21+ tree patches) More patch cover than individual tree cover
Vertical	*Height Differentiation Index* Higher median value following thinning	$CV_{patch\text{-}wise\ heights}$ Higher median value following thinning

Results – Non-spatial structure

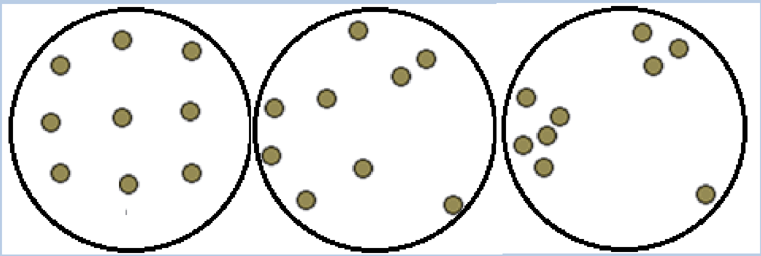
Stand-averaged structure

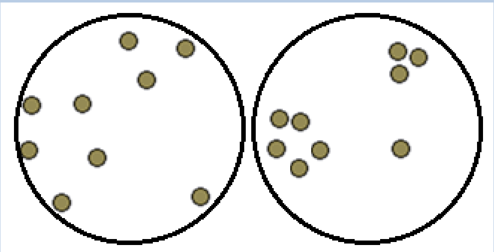
Measure	Pre	Post	Change
[redacted]			
BA (m^2 ha^{-1})	**14—26**	**7.5—20**	**23—62% decrease**
[redacted]			
HT (m)	**10—22**	**10—26**	**3—27% increase**
[redacted]			

- In 5 of 7 sites, increased canopy base height (median crown height)
- All sites increased canopy height (90th%ile tree height)
- In 4 of 7 sites, decreased mean surface fuel load (2 w/ no change)
    - In one site 1-hr fuels increased, litter decreased

Restoration impacts on horizontal complexity

At the stand level





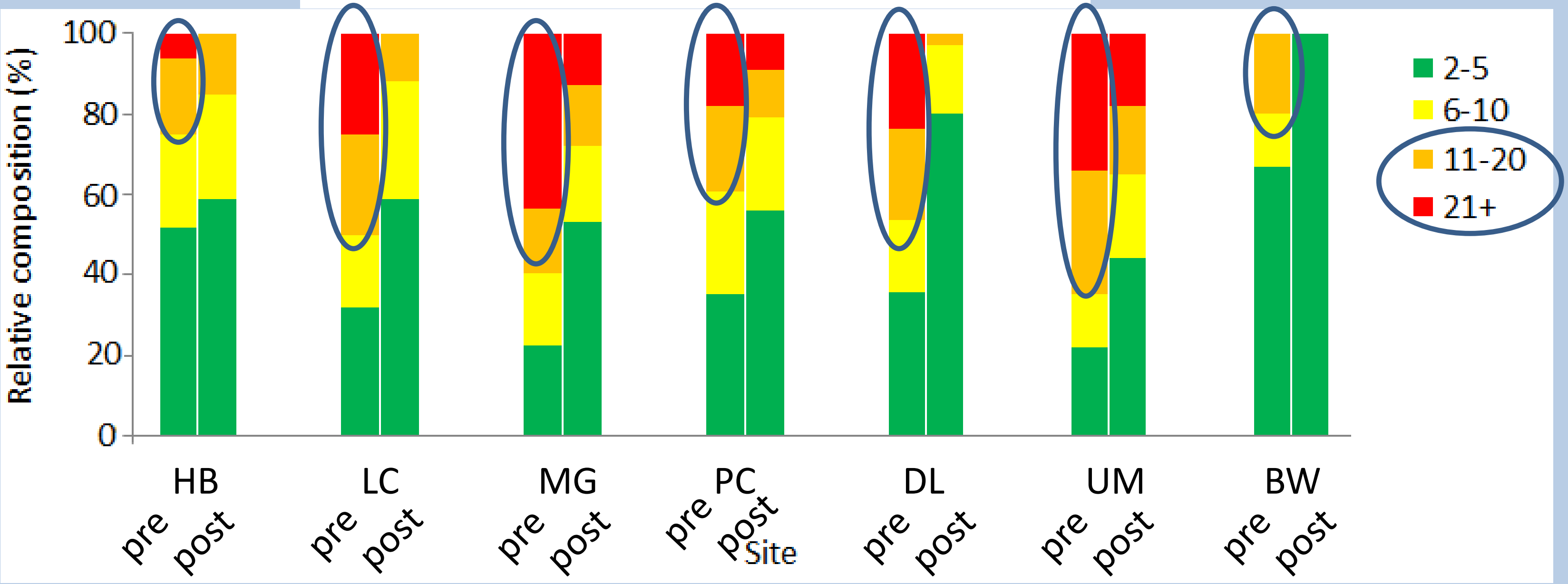
Site	Pattern, pre-thin	Pattern, post-thin	Δ degree of aggregation
[redacted]			
LC	Agg	Agg	Less
[redacted]			
PC	Agg	Agg	**More**
[redacted]			
UM	Agg	Agg	Less
[redacted]			

Restoration impacts on horizontal complexity

At the patch level

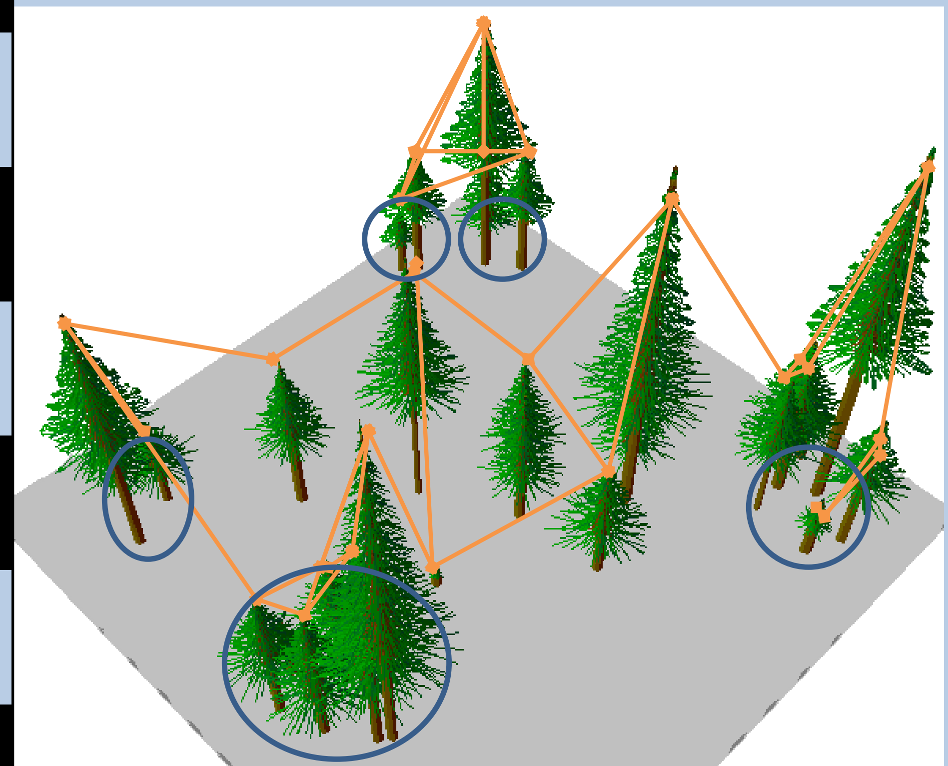
- **Cover of individual trees ranged from 4—8%**
- **All thinnings decreased area of continuous cover patches (>20 trees) and 11 – 20 trees**

Patch size (# trees/ patch) distribution.



Restoration impacts on vertical complexity

Site	Stand Δ	Patch Δ
LC	Less	Less
PC	**More**	None
UM	Less	None



Discussion—Implications for management

The net change in complexity is influenced by silvicultural tactics

- Removal preference of smaller trees
- Thinning within patches
    - Especially ‘ladder’ fuels
- Thinning around select trees

- Creation of openings
    - Concentrated vs. dispersed thinning
- Thinning outside of patches, or in less dense areas

Discussion—Implications for management

Is it appropriate to assume modern forests are structurally homogeneous?

Before thinning,

- 6 of 7 sites were aggregated
- Smaller patches were frequent
- Some vertical complexity occurred

— Space-based processes still occur in modern, fire-excluded stands

Discussion—impacts on structural complexity

Thinnings avoided wholesale shifts of homogenization

Post-thinning patterns..

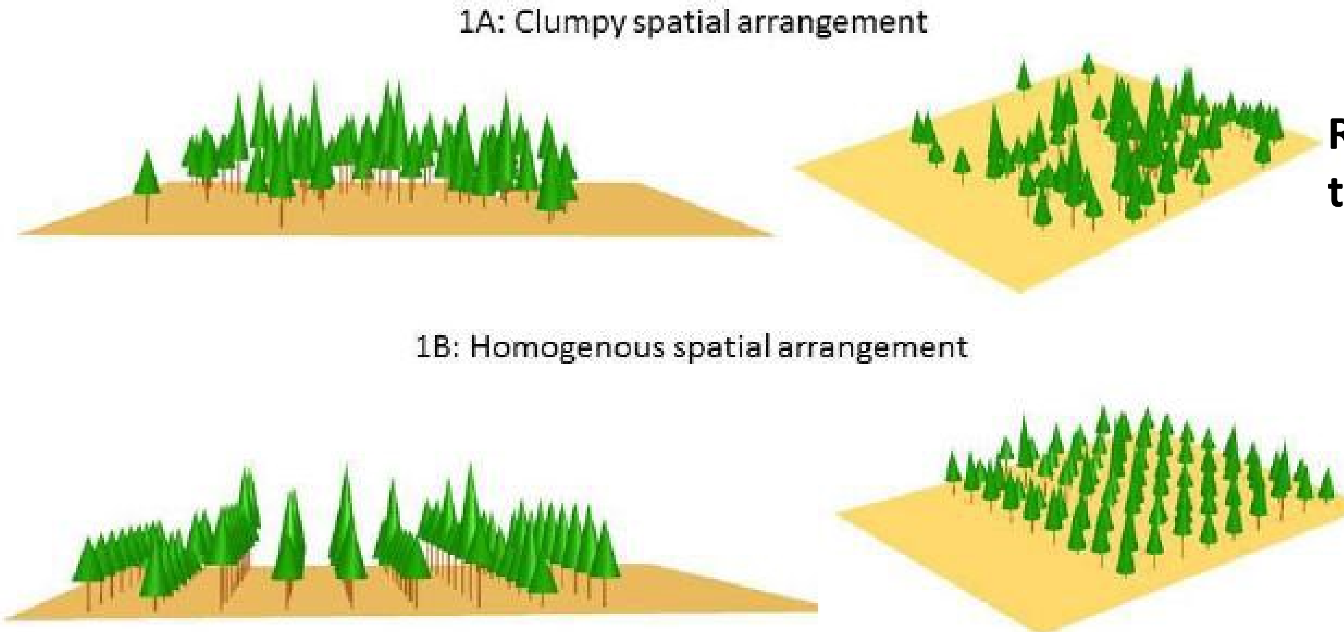
- Avoided uniformity of tree patterns and predominance of continuous cover patches

- Retained some degree of vertical complexity

In contrast, the pre-thinning pattern in HB was uniform

- Attributable to fuels reduction 10 years prior

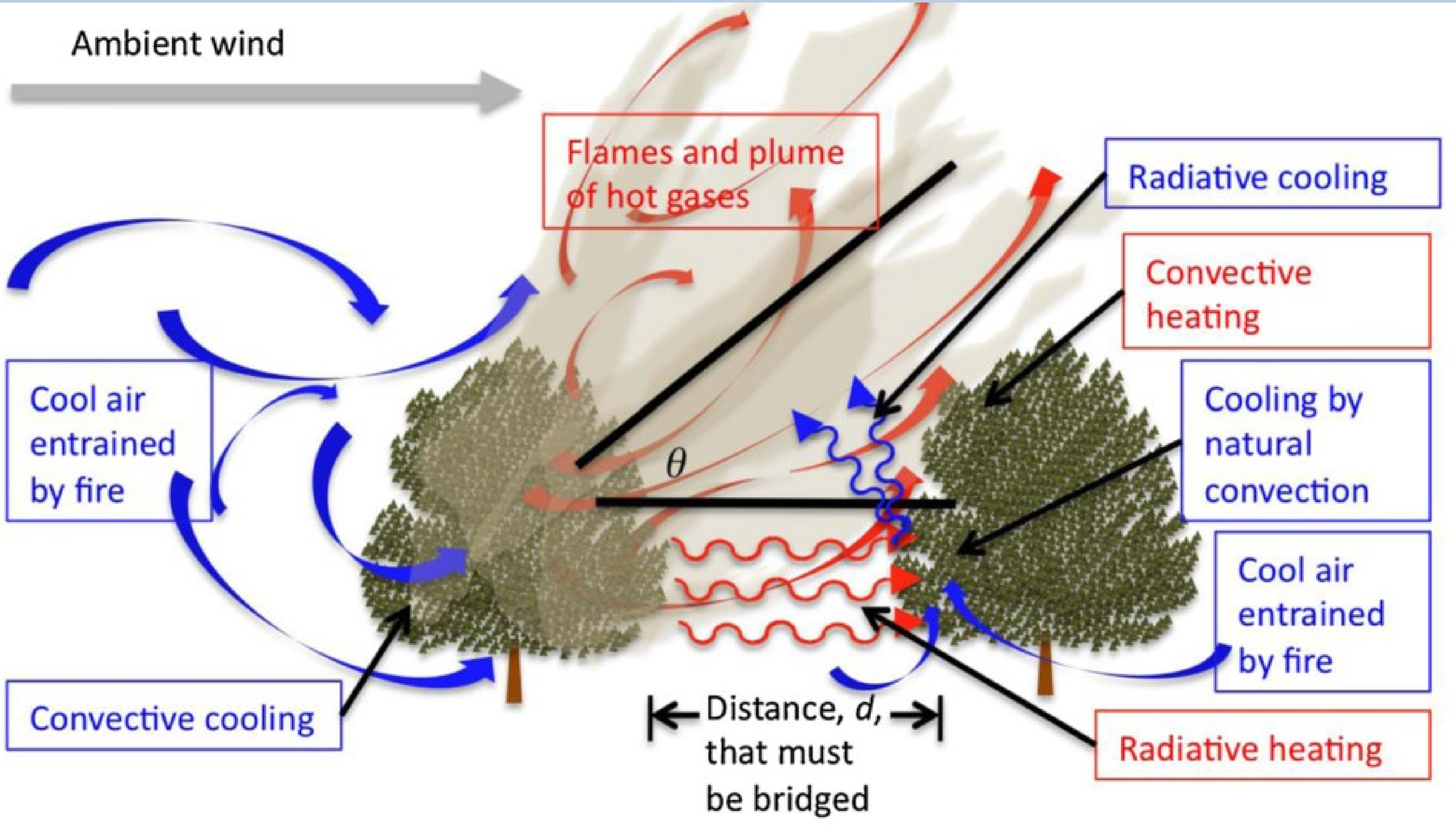
Spatial patterns of trees will likely lead to differences in fire behavior



Restoration treatments

Fuel hazard reduction treatments

The fire environment



Linn et al. 2013

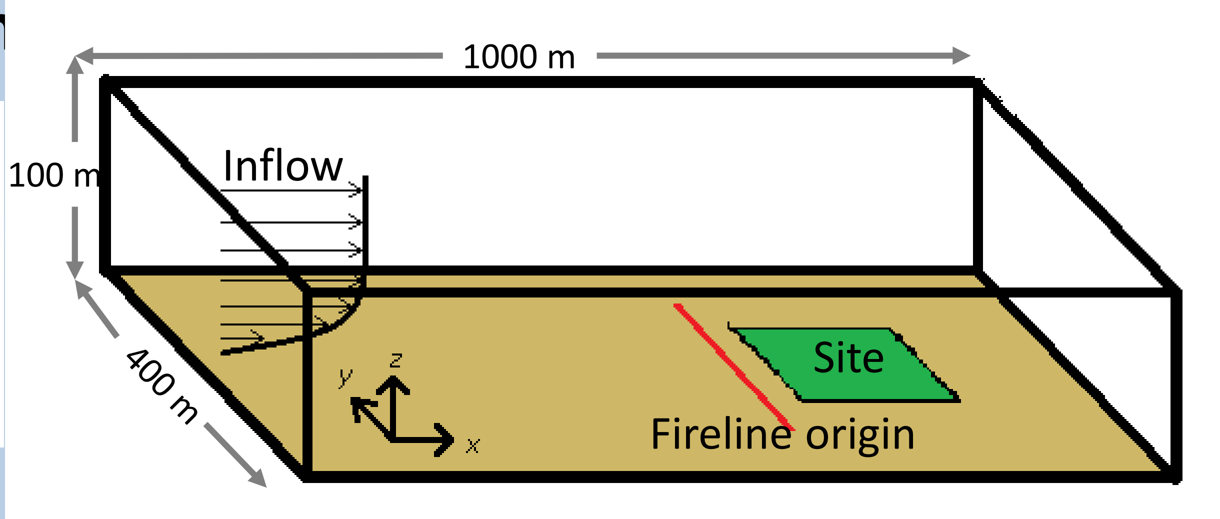
Evaluating fire behavior – Physical approach

Wildland Urban Interface Fire Dynamic Simulator (WFDS)

- Developed by NIST and the USDA FS
  - Uses computational fluid dynamics methods to solve for mass flow, and models combustion and heat transfer
- Couples fuels, fire and weather to produce temporally and spatially explicit predictions of fire behavior
- Research emphasis..
  - High potential to improve conceptual models of fire behavior, generate hypotheses and guide observational studies

WFDS simulation framework

- 7 field-measured sites simulated
- Pre- and post-thinning
  - Populated tree locations with measured crowns
  - Surface fuels – mean load & depth (shrub, herb, litter, 1-hr)
- 4 wind speeds
  - V. low (2.2 m s^{-1}), low (4 m s^{-1}), mod. (9 m s^{-1}), high (13.4 m s^{-1})
- 100% crown and 5% surface fuel moisture
- Line fire ignition

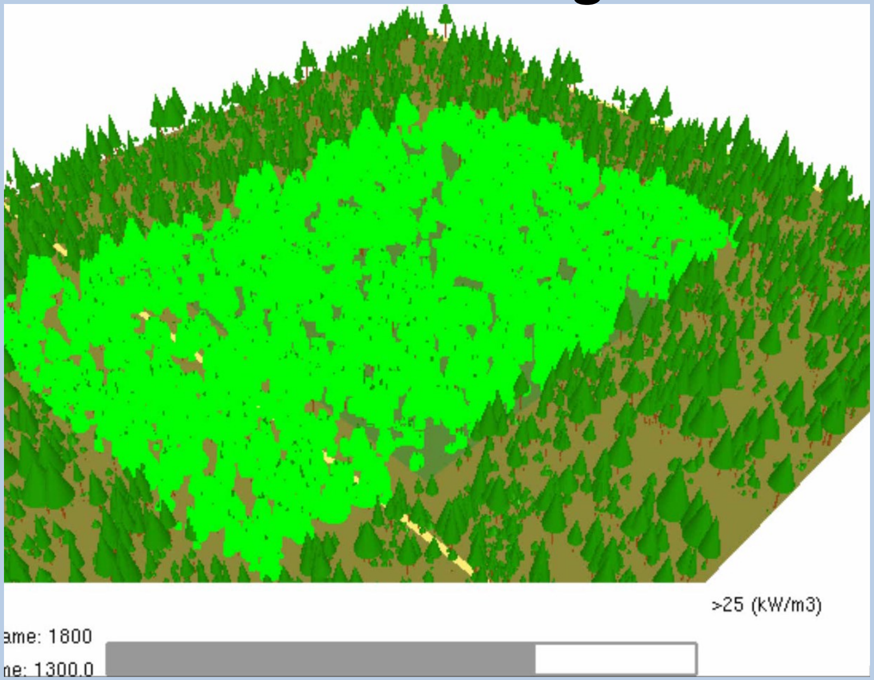


WFDS simulation results

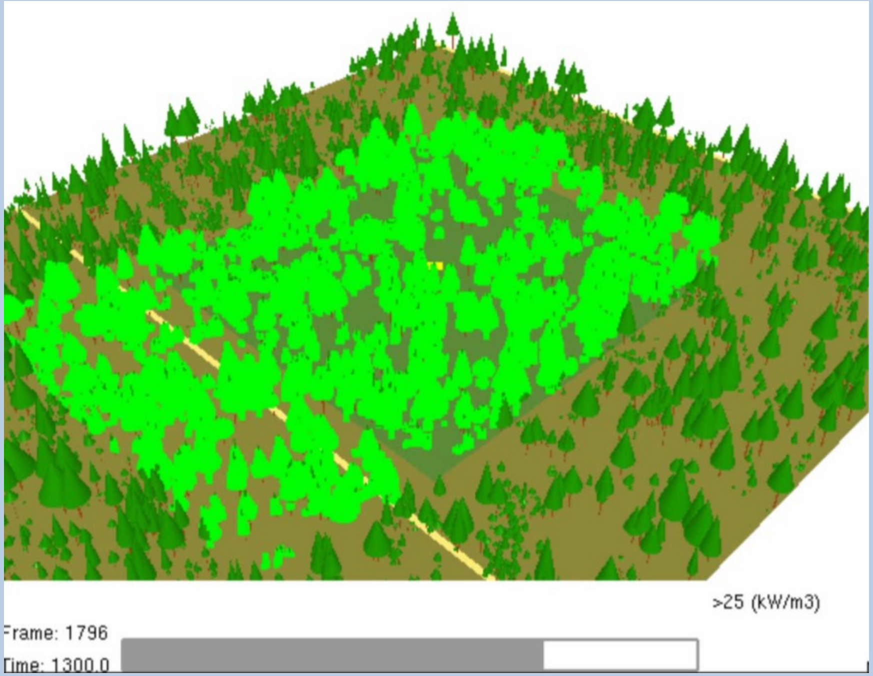
Site: UM

Wind scenario: High

Pre-thinning



Restoration

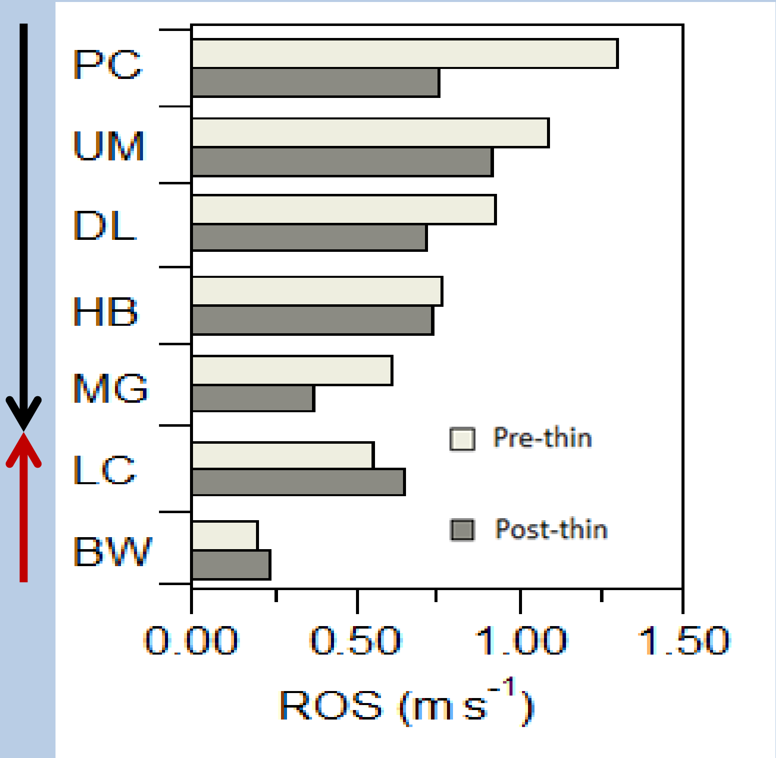


Rate of Spread: 1.8 m s^{-1}
Fireline intensity: ~100,000 kW/m
% Canopy consumed: 80%

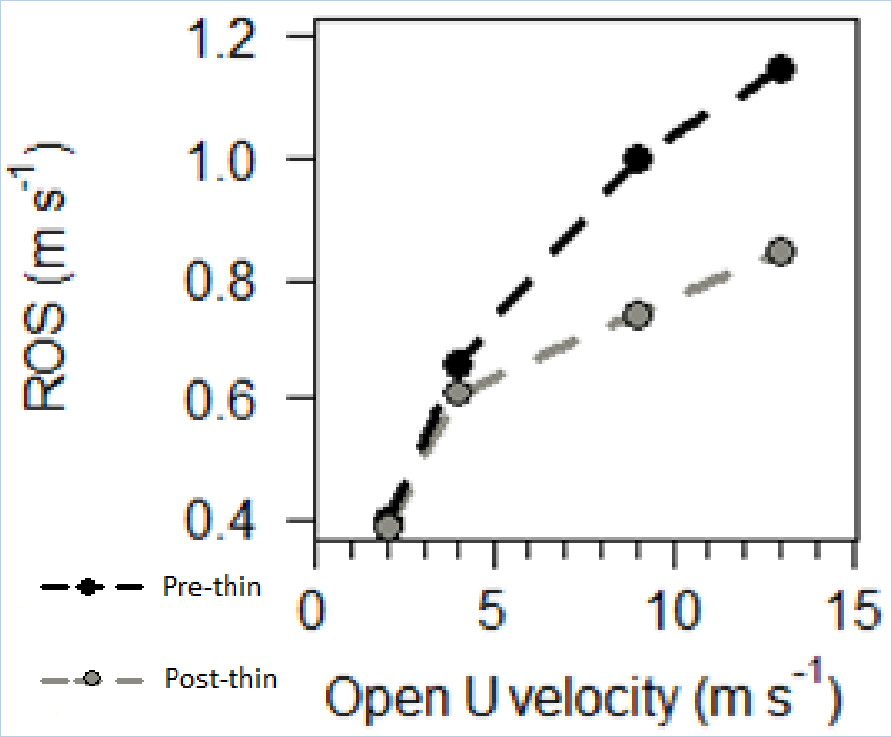
Rate of Spread: 1.4 m s^{-1}
Fireline intensity: ~35,000 kW/m
% Canopy consumed: 50%

Rate of Spread

- Decrease in 5 of 7 sites
- Increase in 2 of 7 sites (LC & BW) – still lower
- Overall, as the wind speed increased, the restoration treatments had lower ROS



By site
averaged over wind scenario

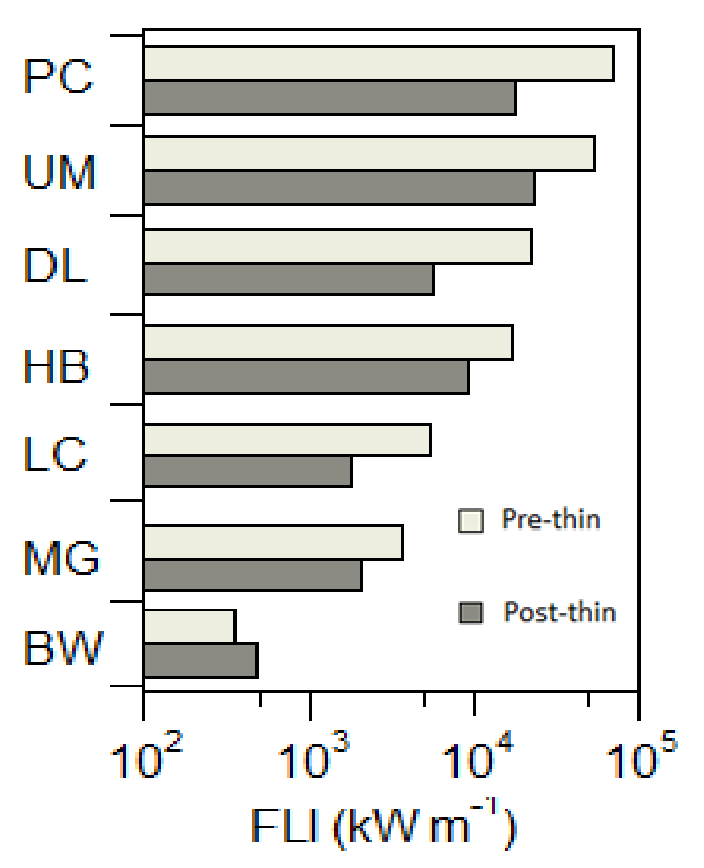


By wind scenario
averaged over sites

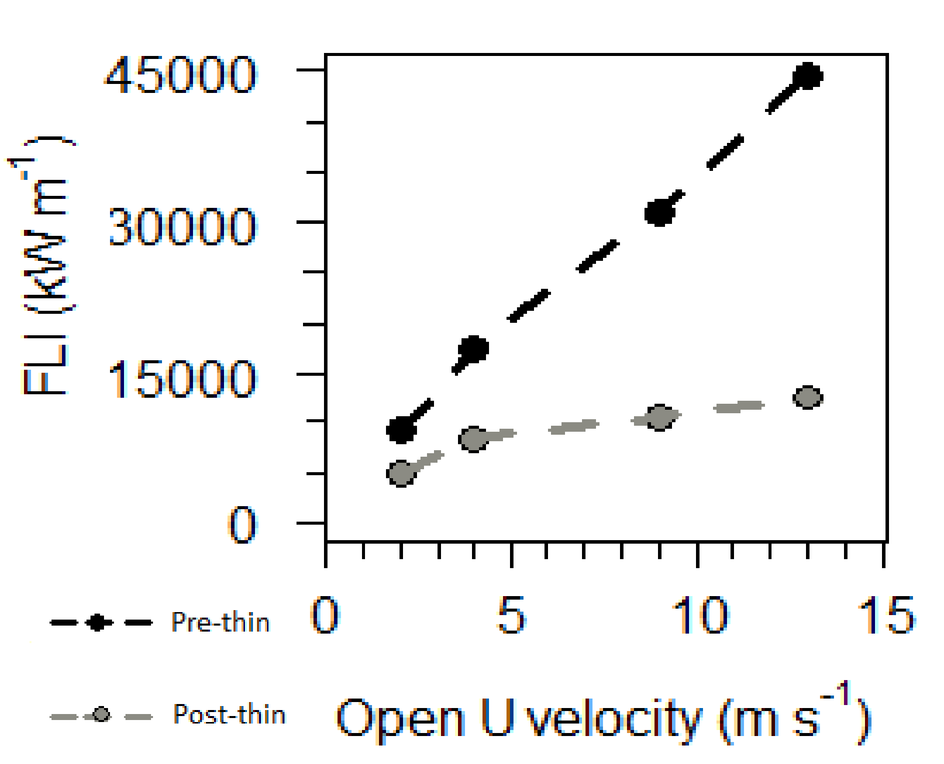
Fireline intensity

Reduction in all but 1 site (BW)

- In those 6, reduction increases with open wind speed



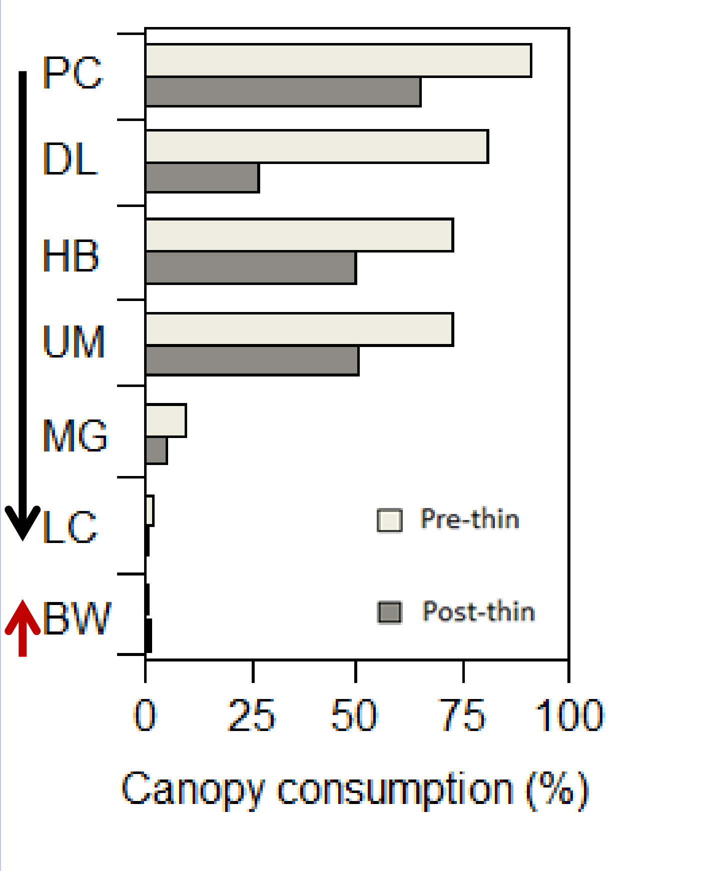
By site averaged over wind scenario



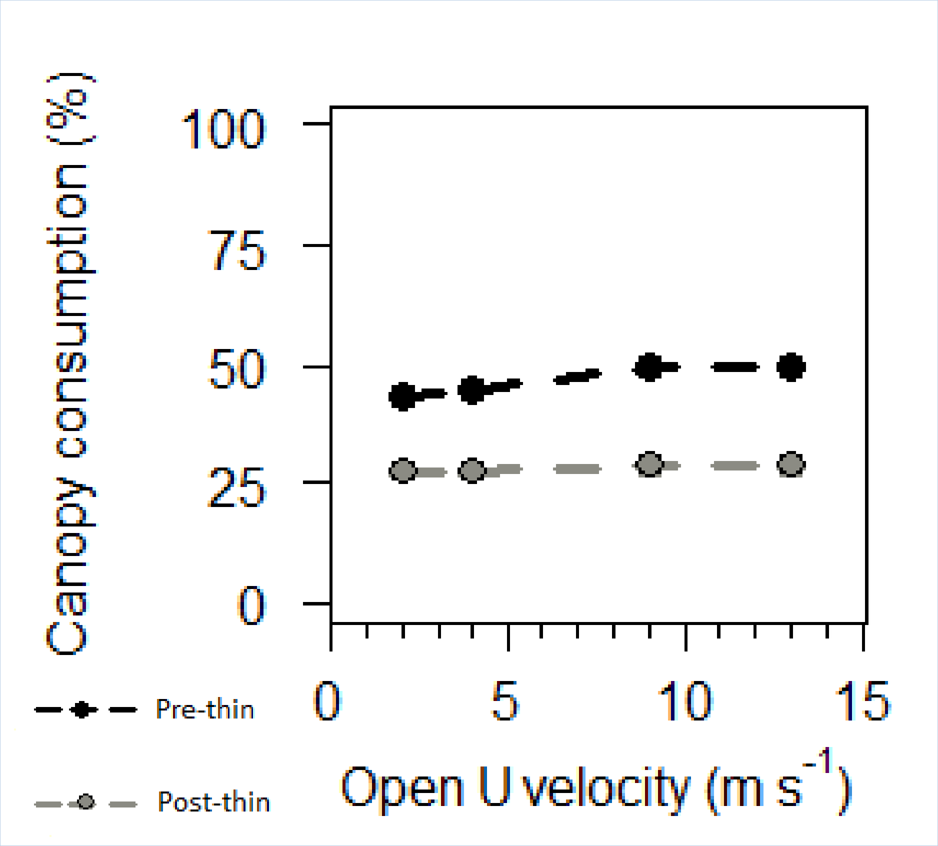
By wind scenario averaged over sites

Canopy consumption

- Again, reduction in all but 1 site (BW)
  - No clear dependence on open wind speed



By site averaged over wind scenario



By wind scenario averaged over sites

Discussion— thinning impacts on fire behavior

In sites LC and BW

- **Crown fire hazard was low prior to thinning**
- **Higher within-canopy winds exacerbated fire behavior but was still lower than other restored sites**
- **Did not lead to crown fire behavior**

In sites PC, UM, DL, HB and MG

- **Crown fire hazard was high prior to thinning**
- **Effectiveness increased with within-canopy wind speed**

Conclusions— management implications and fire behavior

- **Restoration of spatially complex forest structures can reduce crown fire hazard**

- **Restoration thinnings can rectify past homogenizing thinnings (i.e. site HB)**

- **Fire hazard reduction may only be effective in stands with high crown hazard prior to thinning**

Questions?

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